QUARRYING PROCESS AND QUARRY PRODUCTS

We take many things in the material world for granted, not realising or appreciating their presence or value. Construction materials that make up the material world around us come into this unconscious, "invisible" category. Though you see buildings, roads, footpaths and bridges every day, its almost certain that you have never thought about what the materials are, what they are made of, or where they come from. The vast bulk of our built environment is formed from raw materials won from the earth by the extractive industries. Without the raw materials with which to build houses, hospitals, schools, factories, roads, etc., life would certainly be more basic and less comfortable than we presently experience.

Stone quarrying is the multistage process by which rock is extracted from the ground and crushed to produce aggregate, which is then screened into the sizes required for immediate use, or for further processing, such as coating with bitumen to make bituminous macadam (bitmac) or asphalt.

The process begins with a detailed three-dimensional survey of the quarry face. This allows the explosives engineer to design the blast and to plot where the shot holes should be drilled so that the blast can be carried out safely and efficiently. The survey will show if there are any bulges or hollows in the face. A bulge will need more explosive than normal to ensure that it is completely fragmented and not left in place in the face. Hollow areas require less explosive than normal. The placement of explosives is professionally planned to ensure that the required fragmentation of the rock is achieved with the minimum environmental impact.
After the **face profiling** survey, the drilling contractor arrives. Using an air operated drilling rig, he drills the number of shot holes required, at the marked spots corresponding to the hole positions on the blast design, at the angles and depths required.

After the shot holes have been drilled, they are surveyed to check that they correspond to the blast design and the two surveys are combined to allow the blast engineer to work out how each shot hole is filled with explosives.

On the day of the blast, the explosives are delivered and taken to the site of the blast. Detonator cord is placed in each hole and the holes are then loaded with high explosives to within a few metres of the top. The remaining depth is "stemmed" with quarry dust or fine aggregate. The site is cleared. Sirens are sounded to make sure that everyone nearby is warned. The detonators are connected to the electric trigger wire and the circuit is checked. A final safety check is carried out and only when the final all clear is given does the shotfirer set off the explosives. A single blast can fragment up to 20,000 tonnes of rock.

After the blast, the face and **shotpile** (sometimes called the **muck-heap**) are inspected to check that all the shot holes have fired correctly. The face shovel or loader then tidies up the shotpile and starts to load the dumper trucks that take the rock to the crusher. Boulders which are too big to go through the crusher are set to one side for secondary breaking at a later date. Secondary breaking is typically done using a hydraulic digger fitted with a rock hammer, though crawler cranes with steel drop-balls may be used in some quarries.

Crushing can be done in three or four stages, **primary** (first stage), **secondary** (second stage), **tertiary** (third stage) and, in some quarries, a **quaternary** (fourth stage). Crushed rock, or product, is transported along the process line on conveyor belts or down chutes.
The primary crusher is fed via a chute and vibrating feeder. The base of the feeder is made of steel "grizzly" bars and it is here that the first screening operation is actually done. Fine material and dust produced by the blast, along with any remaining subsoil or weathered rock from the top of the quarry face, drops through the bars onto a separate conveyor belt and onto a stockpile. This screened material is called scalpings and is used as rock fill.

Primary crushing is usually by a jaw crusher consisting of a heavy metal plate which moves backwards and forwards against a fixed plate (these are the "jaws"). The
moving plate is kept in motion and given its crushing energy by a large flywheel. The crusher is wider at the top than at the bottom. Rock from the quarry face is fed into the top of the crusher and crushed rock falls out of the bottom of the jaws. The size of the crushed stone which passes through the jaws is partly governed by the gap set at the bottom of the jaws, though larger size rocks can pass through if the rock being crushed is slabby or elongate in shape. Large scale **gyratory crushers** can also be used.

The output from the primary crusher is conveyed onto the primary stockpile from which the secondary crusher is fed. There is a screen house just after the secondary crusher which screens out small size crushed stone and dust onto **blinding stockpiles**. The larger sized stones pass through to the final crushing stages where they are fed through a series of cone crushers and screens. The output from the final cone crushers is conveyed to a screen house where large multiple deck screens sort the crushed stone into the required aggregate sizes.

Secondary, tertiary and quaternary crushers are generally **gyratory**, or **cone**, crushers. These operate on the principle of a steel **mantle** mounted on an eccentric bearing and vertical shaft assembly. Rotation of the eccentric assembly makes the mantle gyrate within a static outer **concave**. There is a gap between the mantle and the concave. The shape of the gap is tapered towards the base. As the mantle gyrates inside the concave, the gap between it and the concave at any one point opens and closes on each gyration, this produces the required crushing action. Stone is fed in at the top and crushed product falls out from the bottom of the cone. The mantle can be raised or lowered within the concave, allowing the gap, and therefore the size of the crushed product, to be varied to a limited degree. If the crusher is jammed by a stray bit of steel,
e.g., a digger bucket tooth, the mantle automatically moves down to clear the obstruction.

Each stage of crushing produces progressively smaller sized stones. In order to produce a usable end-product, the crushed rock has to be **screened** into various size categories. Crushed and screened rock is called **aggregate**. Screening is carried out at various stages in the crushing process. Screens are basically box frames into which sheets of screen meshes of the required apertures are inserted, clamped and tensioned. Screens are usually "multi-deck", i.e., two or more screen meshes are stacked vertically within the screen frame. The whole screen is coupled to its support frame by springs or resilient rubber mountings. Screens are made to vibrate by a rotating transverse shaft. The shaft is machined to be unbalanced, and when driven by an electric motor by v-belts, the required vibratory motion to agitate the aggregate is imparted. Screen decks are mounted at an angle so that the aggregate moves down them. Aggregate is fed onto the high end of the top deck and the vibration causes the aggregate to jiggle down the screen until it either drops through a mesh aperture or falls off the end of a deck. The aggregate is then sorted or 'screened' according to the mesh sizes fitted, from large aperture mesh at the top, to small aperture mesh at the bottom.

Final screens are typically mounted in a screen house over large bins or hoppers into which the different sizes or grades of aggregate are fed. The hoppers are raised on
legs so that trucks can drive under them to be loaded. Material is continually drawn from the storage bins for immediate use (e.g. in a coating plant) or for transfer, either by dump truck or conveyor, to storage stockpiles in the quarry.

Note that size designations are now aligned to the grading categories given in BS EN 13043, which was implemented in the UK from 1 January 2004. Screened stone is known as screenings or aggregate. In the United Kingdom and Ireland, typical screened aggregate sizes are 20/40 (formerly 40mm), 20/32 (nearest fit to former 28mm), 10/20 or 14/20 (formerly 20mm), 6.3/14 or 8/14 (formerly 14mm), 4/10 or 6.3/10 (formerly 10mm), 2/6.3 or 2.8/6.3 (formerly 6mm), and 0/4, 0/5 or 0/6 (depending on top size) (formerly quarry dust).

Note that the limiting sizes are based on laboratory test sieves with a square aperture (small aperture sizes are of woven wire mesh, larger sizes of perforated plate). In contrast, screen mesh apertures are, as a rule of thumb, 2 mm greater than the specified sieve sizes. This is to account for screening plant efficiency (which is less compared to highly controlled laboratory sieving). Screen mesh sizes are chosen with regard to the nature of the aggregate being crushed (e.g., shape – cubical, flaky, elongate, or any combination), and the characteristics of the screen (e.g., screen efficiency, throughput, and whether screen is over, under, or correctly loaded).

**QUARRY PRODUCTS**

A stone quarry typically produces the following products:

- Large size blocks blasted from the quarry face, from approximately 0.5 m³ (approximately 0.36 tonne weight) to 1.25 m³ (approximately 5-6 tonne weight), are called rip rap or rock armour and are used in coastal and river flood defence schemes to shore up sea fronts and river banks.

- Rubble drawn direct from the shot pile is called face fill and is used as large scale fill on construction sites.
• Material screened immediately prior to primary crushing is called **scalpings** or grizzly which is again used as fill on construction sites.

• The direct, unscreened output from a crusher contains a complete mix of sizes from dust up to the maximum size that the crusher can pass. Output from the primary and secondary crushers is fed, unscreened, to intermediate or separate stockpiles. Material drawn from these stockpiles is called **crusher run** and is used for construction fill.

• Screened out fine material from the secondary crusher is called **blinding**. Some screens have multiple decks and can screen out several grades of blinding. As with crusher run, blinding materials contain a mix of sizes, from the maximum size that the screen mesh can pass, down to dust. Blinding, because it is finer than crusher run, is used for final shaping up of construction sub bases, particularly in road construction, where the sub base is the last unbound layer before coated materials are laid.

• Screened aggregate (ballast) for concrete.

• Screened aggregate is heated and mixed with bitumen, according to certain recipe proportions, to make different grades of bituminous *macadams*, or, mixed with sand, ground limestone filler and bitumen, to make **hot rolled asphalt**.

[*Colloquially called bitmac or tarmac. The words tar or tarmac, though very frequently used, are incorrect as tar is no longer available. For coated materials, bitumen, derived from the distillation of petroleum crudes, has been in almost universal use as a binder for the last four to five decades.*]

• 32/50 is used for **railway ballast** and as **filter media** in water treatment plants (if the rock type is tough enough).

• Most Category Gc aggregates can be used as a trench fill **drainage stone**, as the void space between aggregate particles allows water to flow through.

• If the rock quarried is resistant to the polishing action of vehicle tyres, aggregate of size 14/20 Gc 85/20, when coated with 1½% bitumen, is called **pre-coated chippings** or **pre-coats**. Such chippings go on the surface of the **hot rolled**
asphalt which surfaces many roads in the British Isles. The chippings are distributed in a single layer direct onto the laid asphalt and rolled into it while it is still hot. The chippings help give the asphalt a rough surface texture, which together with the stone’s resistance to polishing, provides grip to the surface which allows vehicles to brake and stop safely.

Every summer, large quantities of 2.8/6, 6.3/10 and 8/14 Category C aggregates are used to surface dress many roads. Surface dressing is a cost effective remedial process which seals, restores grip and prolongs the life of the road treated. Surface dressing is carried out by a large squad of men in a military-like operation (see photo 1). The road is first swept by a suction sweeper. The bitumen sprayer (see photo 1) then sprays half the road width with a bitumen emulsion or a cutback (fluxed) binder. The sprayer is then followed by one or more gritters (see photos 2 & 3) which lay down a layer of chippings ahead of themselves onto the sprayed binder. Gritters have a rear hopper which receives aggregate from the delivery lorries. Aggregate tipped into the gritter is transferred by conveyor to the front driving end and distributed across the width of the gritter by auger screws and a fluted distribution drum. Finally rubber tyred rollers follow up, rolling the chippings firmly into the binder (see photo 4).

Surface dressing is universally disliked by motorists due to the risk of broken windscreens or chipped paint from loose chippings. This usually happens when vehicles are driven too fast on freshly dressed roads. As with all road construction sites, drivers and their vehicles will be safe from accidents if all the traffic signs posted are obeyed. The treated road will be finally suction swept after the chippings have firmly bedded into the binder. Bedding-in usually takes a day or two.